SMART WEAPONS OPERABILITY ENHANCEMENT

USAF ARMY NAVY DARPA

SWOE

Program Implementation Plan

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U.S. Army Cold Regions Research and Engineering Laboratory
Hanover, NH

SWOE Report 88-1
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FOREWORD

SWOE Report 88-1, January 1989, was prepared by Dr. J.P. Welsh, Dr. L.E. Link, H.S. Farquhar, R.K. Redfield and R.A. Palmer of the U.S.Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire.

This report is a contribution to the Smart Weapons Operability Enhancement (SWOE) Program. SWOE is a coordinated, Army, Navy, Marine Corps, Air Force and DARPA program initiated to enhance performance of future smart weapon systems through an integrated process of applying knowledge of the broadest possible range of battlefield conditions.

Performance of smart weapons can vary widely, depending on the environment in which the systems operate. Temporal and spatial dynamics significantly impact weapon performance. Testing of developmental weapon systems has been limited to a few selected combinations of targets and environment conditions, primarily because of the high costs of full-scale field tests and limited access to the areas or events for which performance data are required.

Performance predictions are needed for a broad range of background environmental conditions and targets. Meeting this need takes advantage of significant DoD investments by Army, Navy, Marine Corps and Air Force in 1) basic and applied environmental research, data collection, analysis, modeling and rendering capabilities, 2) extensive target measurement capabilities and geometry models, and 3) currently available computational capabilities. The SWOE program takes advantage of these DoD investments to produce an integrated process.

SWOE is developing, validating, and demonstrating the capability of this integrated process to handle complex target and background environment interactions for a world-wide range of battlefield conditions. SWOE is providing the DoD smart weapons and autonomous target recognition (ATR) communities with a validated capability to integrate measurement, information base, modeling and scene rendering techniques for complex environments. The result of a DoD-wide partnership, this effort works in concert with both advanced weapon system developers and major weapon system test and evaluation programs.

The SWOE program started in FY89 under Balanced Technology Initiative (BTI) sponsorship. Present sponsorship is by the U.S. Army Corps of Engineers (lead service), the individual services, and the Joint Test and Evaluation (JT&E) program of the Office of the Director of Defense Research and Engineering (DDR&E), Office of the Secretary of Defense (OSD).

The Program Director is Dr. L.E. Link, Technical Director of the U.S. Army, Cold Regions Research and Engineering Laboratory (CRREL). The Program Manager is Dr. J.P. Welsh, CRREL. The Integration Manager is Mr. Richard Palmer, CRREL. The task areas and their managers are as follows: Modeling Task Area, LTC George G. Koenig, USAF, Geophysics Laboratory (GL), of the Air Force Phillips Laboratories; Information Bases Task Area, Mr. Harold W. West, PE, U.S. Army Engineer, Waterways Experiment Station (WES); Scene Rendering Task Area, Mr. Mike Hardaway, Corps of Engineers, Topographic Engineering Center (TEC); Validation Task Area, Dr. Jon Martin, Atmospheric Sciences Laboratory (ASL) of the Army Materiel Command.

PROGRAM IMPLEMENTATION PLAN January 1989

1. Program Title

Smart Weapons Operability Enhancement (SWOE)

2. Management Information

Dr. Lewis E. Link, Jr., Program Director, Dr. J. P. Welsh, Jr., Program Manager, U.S. Army Cold Regions Research and Engineering Laboratory, 72 Lyme Road, Hanover, NH 03755. (Commercial) 603-646-4527. Primary contracting Officer is Ms. Sylvia Marsters, USACRREL (CRREL-LM-CT).

3. Purpose of Effort

To provide the smart weapons and autonomous target recognition (ATR) communities with a validated integrated capability to use measurements, information bases, modeling and scene simulation to effectively consider and exploit the complex environment of world wide battlefields. This capability will be produced by a DoD-wide partnership working in concert with advanced weapon designers and developers and major weapon test and evaluation programs. Specifically, information and analytical tools that comprehensively treat the environment in terms significantly relevant to weapon and sensor performance will be developed and demonstrated for two primary user communities: "designers/developers" and "testers/evaluators".

4. Short Term Goals (91-92)

Provide the proof-of-principle tester with guidelines on what, where, when, and how to characterize, analyze, and document the environment to understand test results for IR and MMW systems. This will include what parameters must be measured, how, where and when to make measurements, and the expertise to assist in applying the data to test results. This short term goal is primarily integrating existing information and procedures for demonstration at scheduled developer tests.

Develop prototype (representative) databases of environment factors tailored to advanced weapon applications for European (high and 'low latitude), desert and tropical test sites. These databases will be used to (1) begin the correlation of system performance at test sites to conditions expected in an operational deployment area and (2) to exercise and verify models and simulations. The most significant technical issues are the development of cloud cover statistics and extension of 4-D (3 spatial and I temporal dimensions) environment and atmosphere models to consider and accurately represent the temporal and spatial character of surface features relevant to image metrics and advanced weapon /ATR system performance.

Integrate the most advanced existing IR and MMW surface, atmosphere, and feature models with scene generation capabilities for demonstration and verification. This goal is directed at integrating existing first principles models and empirical models as needed to generate an initial capability to develop scene data sets for specific developmental system trade-off analyses. The most significant technical issue is the definition of surface

feature edge and texture properties for realistic representation of image properties relevant to metrics used for weapon logic design.

5. Long Term Goals (93-96)

Complete prototype environment data sets for selected OCONUS battlefield conditions and CONUS test sites tailored for weapon performance and effectiveness evaluation. These will include climate, terrain, weather and atmospheric data that are relevant to the interaction of IR and MMW energy with the environment and system performance. These representative data sets will define the dominant conditions in which a system must perform for a specific deployment area and provide the basic input for modeling and simulation procedures to generate tailored image data sets.

Provide capability to the DT&E community to relate results from limited sets of test site condition information (data) to other areas of the world (National defined strategic deployment areas). The key technical issue is to develop the ability to infer key environment parameters affecting system performance from fundamental data such as classical climate and surface data sets.

Provide users with first principles, 4-D environment signature models (with all pertinent environment features, including the atmosphere and weather) for (1) relating and predicting system performance between various sets of environmental conditions and (2) generating physically correct image simulations. Key technical issues include (1) relating/modeling and empirical inputs to first principles MMW model to physics of background; (2) modeling spatial and radiometric variability (moving from I-D to 3-D spatial models); (3) accounting in the models for the natural variability encountered in nature for active IR; (4) integrating atmospheric and surface models; and (5) 3-D spatial models of clouds relevant to IR and MMW system effects.

Provide users with the ability to generate physically realistic image data sets for specific system and environment condition combinations as required for tradeoff analysis, metrics development and logic design. Key technical issues include (1) developing realistic treatment of edges and texture from a physically-true basis; (2) integrating first principles models and information bases with scene generation capability while maintaining reasonable storage and computational requirements; and (3) determining basis of scene generation (scene or wavelength). Define physically-based scene/image metrics, including the ability to determine which image features are artifacts of perspective and illumination and which are scene properties that will offer consistent metrics for logic design. The key technical issue is the correlation of the physical attributes of surfaces and atmospheric conditions with specific metric values and defining the impact of the imaging process on metric values and robustness.

6. Relation to other Programs

The problems this program seeks to solve have been recognized for a long time by the DoD environmental research and sensor development communities. Because the magnitude of the problem was deemed to be to complex to systematically address, the sensor development community made a deliberate decision to take a heuristic approach to smart/ATR sensor development. However, based on the limited success and relatively

resource intensive nature of that approach, that community recognizes the need for parallel development of a first principles capability to consider the environment in the DT&E process. In the meantime, considerable tech base funding has been invested in defining the very complex background/operational environment and its effects on smart/ATR sensing technologies. These efforts have provided the advances in knowledge that make the proposed work a productive endeavor. The ongoing tech base work (see paragraph 5) will continue to feed this effort with the basic capabilities to create and demonstrate user specific capabilities that systematically incorporate the environment into smart/ATR system DT&E. As such, the tech base efforts and this program, which represents the focusing, integrating and demonstrating of these technologies/capabilities for specific development community needs, are integral parts of an overall effort. No comparable effort exists to combine the expertise and resources of the DoD environmental science community with those of the weapons development community to comprehensively address these critical issues. Existing measurement and testing resources as well as scheduled developmental system T&E will be exploited. Through the partnerships established, validated products will be incrementally incorporated into the operational capability of the DT&E community throughout the life of the program. The program has already served to begin extensive coordination between the Army, Navy and Air Force.

7. Transition

The primary products of this effort are not hardware but technology to support the development of hardware. As such the products must be integrated with the design, test and evaluation methodologies used by the development community and their contractors. Specific developer initiatives have been identified as targets for incorporation of the SWOE technologies as follows: SWOE PRODUCT PRODUCT APPLICATION.

Standard (representative) Electronic Terrain Board (C2NVEO)
Environment/Background Data Hardware-in-loop Simulator (MICOM, VAL)
Sets Standard Scenes/Scenarios for ATR (C2NVEO) Smart Weapon
Evaluation Workstation (JTCG) Test Performance Relevance (Chicken Little)

Test Site/Test Results ROC Environmental Definition (ARDEC/SADARM)
Quantification and Validation Field Test Documentation (C2NVEO, ARDEC, Chicken Little, SPAWAR, TECOM and DARPA)

Field Test Data Extension (DARPA, C2NVEO, VAL, TECOM)
Background/Atmosphere System Performance Models (C2NVEO-Terrain Integrated Signature Board, ARDEC-SADARM/WAM, VAL-EVAL model,
Models MICOM-BEWESS Model, BRL-SADARM/SFW, JTCG- Work Station,
AFATL-TABILS Evaluation/SFW)

Physically Based Image ATR Design/Evaluation (DARPA/ARDEC, C2NVEO, Metrics S3TO/MMAS)

Scene Model/Simulation Standard Scenes for ATR Dev (C2NVEO,DARPA) for Tailored Image Data Computer Image Generation (DARPA/MICOM, Generation C2NVEO, BRL, AFWAL, ARDEC-WAM)

The use of image metrics as a primary mechanism to tie the environment to image properties and then to future system performance also provides the connective tissue between the descriptions, characterizations and models of the environmental community with the performance models and analysis methods of the systems development community. The specific schedules for integration of the SWOE products with the developer initiatives are currently being negotiated and will be incorporated in an update to this implementation plan.

8. Program Tasks

Program tasks fall into three major technical areas : Measurements and characterization; Information bases; Modeling for scene generation.

a. Measurement/characterization: It is essential that test site features and conditions, the drivers of their dynamic signature behavior, be documented and available in terms relevant to the performance of the weapon system being tested and evaluated. This task provides the technology necessary to measure and characterize the environment to permit the evaluation of system performance in the field, provide the information to compare and extend/extrapolate results to other sites/conditions and to support and validate modeling of the dominant operational environmental conditions for scene generation.

(1) Characterization Technology: Develop the capability to measure and characterize dominant environmental conditions required to evaluate smart/ATR weapon system performance. Provide guidance to testing community on environmental measurements requirements. Define critical parameters for characterization of static and dynamic site features.

FY89: Definition of critical environmental parameters. Both static and dynamic features of backgrounds and atmospheres must be defined in terms relevant to weapon system performance. Partial BTI funding.

FY89/90: Develop draft characterization handbook for passive thermal IR systems. Handbook will contain information on accuracy, frequency and spatial quality of measurements required for system performance evaluation and model development and validation. Full BTI funding.

(2) Weapon system test support and characterization demonstrations. Specific measurement programs will be conducted as part of proof-of-principle and full-scale development tests for developmental smart/ATR weapon systems. Measurements will provide developers with critical information for performance and effectiveness analysis. Standardization and redundancy of measurements will permit comparison of test information to other locations and conditions. Major characterization demonstrations will be conducted at scheduled multiple- system tests (e.g. Chicken Little Follow-On,

BEST-TWO) to demonstrate the utility and value of technology developed under the program.

FY89: Conduct measurement programs in support of weapon system development tests and prepare for first characterization demonstration of full-scale measurements capability at existing major test scheduled for FY90. Partial BTI funding.

(3) First-principles model development measurement support. Develop environment characterization technology to provide information on variability of dominant environmental features in sufficient detail for model and scene simulation requirements. Conduct focused and highly structured measurement programs to define effects of variability on sensor and logic performance and validate models. Programs will be tailored to fill gaps in existing data bases and to develop crucial field hardened measurement technology. Significant emphasis will be placed on the definition of and role of metrics in the development and performance of decision logics. FY89/90: Development of ground truth technology for quantification of the performance of IR and MMW systems. Initial efforts will involve assessment of existing capability and preparation of recommendation for technology development. Major focus will be to develop fieldable technology for MMW signature/image characterization, especially for application to the 94 GHz spectral region. Full BTI funding.

b. Information Bases: Information bases are required to drive models and scene simulations and provide the information for analysis of system performance and effectiveness. Environmental data sets are needed that describe the dominant static and dynamic features of backgrounds and atmospheres that significantly impact system performance. This task provides for the development of standardized data sets for surface, climate, weather and atmospheric conditions at theater of operation and test site locations, the technology to compare and extrapolate conditions spatially and temporally, and develop methods to estimate parameters which are difficult to obtain but are critical to system performance evaluation.

(1) Develop standardized data sets consisting of digitized surface/ features and concurrent weather, climate and atmospheric data. Initial focus will be on central Europe with eventual extension to other operational areas. Initial data sets will contain information on dominant stable conditions and the dominant conditions which drive changes in the surface energy budget. Further development will result in reference image and scene data bases for calculation of metrics and quantification of "clutter." Duplicate data sets for CONUS test sites will be developed for use in comparison of weapon system test results to operational area requirements.

FY89: Develop prototype digitized surface/feature, weather, climate and atmospheric data sets for Hunfeld, FRG and two CONUS test sites.
Development will make full use of existing data bases but require isolation of those dominant parameters which impact system performance. Full BTI funding.

FY89/90: Expand TACOM/KRC standard scene data base for correlation with IR image metrics. Purpose is to relate image metrics to physically based scene elements. Scene information must be extended to all seasons and have additional time and event sequencing for completeness. This data base can be used to drive prototype models and

scene generation software and will serve to focus efforts on required enhancements. Partial BTI funding.

(2) Develop site/site and area/area comparison methodology. The requirement is driven by the need to be able to relate system performance at a test site to required performance in operational areas. The methodology will be based on the physics of the interactions between weapon system and the environment and not rely on classical parameters not directly relevant to system performance. FY89/90: Initial development of the comparison methodology will consist of statistical analogs of parameters contained in the data bases for the two CONUS test sites and Hunfeld. Specific, preliminary comparisons will be provided to the Chicken Little Project Office (follow-on test site selection/calibration), S3TO (MMAS fusion study and demonstration) and ARDEC (SADARM FSED test results). Partial BTI funding.

(3) Develop parameter estimation methods for deriving specific, critical energy budget parameter values from climate, weather and terrain information. Parametric transforms are needed to estimate parameters which are difficult to obtain and are required to evaluate system performance. Examples of transforms are those relating soil type, moisture content and density to thermal conductivity and soil type and moisture content to dielectric constant. Others are needed to provide a basic parameter estimation capability that will, to some extent, standardize model and analysis inputs for critical parameters not readily measured.

FY89/90: Development of a parameter estimation methodology for parameters critical to evaluation of passive thermal IR systems is a first priority. Initial development will involve study of the variability of available terrain/feature information and its relationship to the prediction of energy budget calculations. Full BTI funding.

c. Modeling/simulation: Analytical models are needed that can simulate the energy budgets and energy interactions with specific feature types (e.g. vegetation, soil, rock, water, ocean, cultural features, snow covers) and atmospheric features (e.g. precipitation, clouds) for the IR and MMW spectral regions. Existing codes will provide a starting point for the development of models which generate three-dimensional, radiometrically-accurate signatures of features sized appropriate to weapon system resolution. There will be particular emphasis placed on the accurate prediction of seasonal, weather and diurnal impacts and the true representation of inherent variance (texture) of the signatures of scene components. Scene components will then be combined to produce static scenes with energy field information that is not influenced by the sensor design and thus will have broad application as an evaluation tool. Image metrics linked directly to physically-based scene elements will be calculated and used to produce realistic measures of "clutter." Significant advances in scene generation capability are required to permit the rapid combination of scene elements with realistic texture and edge characteristics, especially along boundaries of differing scene elements. Development of background model and scene generation technologies will include careful consideration of the configuration of targets models, hardware and software architectures and other user-specific requirements.

(1) Develop comprehensive, first-principles infrared modeling technology for the prediction of background affects on smart/ATR weapon system performance. Models

are required that calculate the energy budget for surface features influenced by weather, time of day and season with application to passive IR systems. Models are required for energy scattering/depolarization prediction for active IR systems. Models of weather and atmospheric conditions that drive the backgrounds models are also required.

FY89: Develop comprehensive I-D thermal surface modeling package. Select the best existing I-D modeling capabilities for combination and improvement. Develop model linkages and extend models were necessary to provide realistic point density for model outputs. Partial BTI funding.

FY89/90: Integrate complete atmospheric/weather modeling package with backgrounds models. Models exist for most atmospheric and weather phenomena but may require revision to be applicable to surface models. Specific attention needs to be focused on top-attack and slant path profiles. Development of cloud models that produce radiometric surface effects and atmospheric image degradation models will be initiated. Partial BTI funding.

FY89/90: Develop statistics on spatial and radiometric variability of backgrounds for application to I-D modeling package. Couple the empirical statistics to the I-D models to produce a composite, hybrid modeling package for surface features. This hybrid model will be used to generate background scenes with texture and edges until the 3-D first-principles models are developed. Full BTI funding.

FY89/90: Initiate development of 3-D first-principles background features models for passive thermal IR. Extend/expand existing I-D models for selected set of features (e.g. trees, rocks, snow patches, artillery craters) which have demonstrated effects on smart/ATR weapon system performance. Models will eventually result in capability to produce physically-based synthetic scenes with accurate edge/boundary and texture effects. Full BTI funding.

FY89/90: Initiate development of active IR modeling package for prediction of surface scattering, reflectance and absorption. Models for full range of terrain/features driven by seasonal, diurnal and weather variations are needed. Partial BTI funding.

(2) Develop first principles MMW surface modeling technology. Models that realistically consider the surface and volume scattering and polarization effects of dominant surface types and features are required. The boundaries between features again pose significant challenges to model development and must be carefully evaluated through measurement programs. Eventual integration of MMW models into scene generation architecture is an additional driver. FY89: Initiate development of the relationship of empirical MMW models to physically-based surface features through linkages with correlation functions. Empirical models exist which can be extended and improved using data from MMW measurement programs. Completion of these linkages will enable eventual inclusion of dominant geometric shapes and components of individual features in first-principles MMW backscatter models. Partial BTI funding.

(3) Develop scene generation and display technology that accurately portrays image signature characteristics for full range of operational environmental conditions. Requirement is to develop technology which permits display of images suitable for calculation of metrics, "clutter" definition and system performance and effectiveness evaluation. Significant considerations are the need to evaluate multi-mode, multi-spectral systems, the requirement for target insertion into the generated background, the availability of hardware and software architectures within the government and contractor community and the requirement to integrate products from multiple producers with different systems.

FY89/90: Initial efforts are to select a hardware/software architecture for implementation of products from the program, produce static image sets from the composite, hybrid modeling package and demonstrate the dynamic scene capability of the architecture using combinations of available measured imagery and interim extrapolation techniques. Existing IR data will be analyzed to determine the character of edges and texture of dominant surface features relevant to image metrics. Methods to correlate image metrics to scene elements will be developed. Partial BTI funding.

9. Associated tasks

The DoD environmental science community currently has programs which are producing basic and applied research products with application to this BTI effort. These programs are funded under different sponsorship. Reductions in funding to these programs and projects would have an adverse impact on this program.

The following is a summary of the funding for Army programs and projects that support this BTI program.

Army	FY89	FY90	FY91	FY92	FY93	Task
61102	384	262	230	280	384	Terrain scene and signature models
	750	750	800	850	850	Winter background signature models, characterization methods
	215	225	350	330	340	Background models, scene generation, climatic database extrapolation
	950	1150	1210	1200	1200	Image degradation, mitigation
62784	375	500	650	525	550	Scene generation, climatic database extrapolation, background modeling
	1130	1550	1600	2150	2150	Weather effects on weapon system performance, backgrounds, atmospheric modeling
	0	110	280	385	350	Application of terrain scene/signature models to sensor based weapons
	950	1050	1150	1050	1150	Winter background models, characterization methods
63734	230	360	375	380	410	Weapons system performance TDA's
65702	2150	2800	3275	3450	3450	Atmospheric measurement/ characterization

The following is a summary of the funding for Navy programs and projects that support this BTI program. The Navy projects address SAR, environmental, meteorological and atmospheric tasks.

Navy	FY89	FY90	FY91	FY92	FY93	Task
6.1	650	850	1150	1200		Environmental
6.2	1300	1300	1350	1400		Environmental
6.3a	800	1000	1400	1600		Environmental

The following is a summary of the funding for Air Force programs and projects that support this BTI program.

AIR FORCE	FY89	FY90	FY91	FY92	FY93	Task
62602F	110	200	200	200	200	IR background modeling
62101F	160	180	200	200	200	2-D cloud simulations
	350	250	200	200	200	Spectral sensors - IR
163707F	2100	1900	1600	1300	1300	TDA's for smart weapons

The following programs are consistent with the goals of this program, do not overlap or duplicate and are complementary to this program.

C2NVEO - Two color FLIR development

AFSC/AD/ENL (Chicken Little) - ERIM Follow-on Background Measurement

Program DARPA - Smart Weapons Program, ATR Weapon Systems Theoretical Underpinning Development

S3TO - MMAS Sensor Fusion Study and Demo

AATD/C2NVEO - Multi-Sensor Fusion Demonstration

10. SWOE Program Resources Summary

The funding profile is divided into major task areas.

Major Task Areas	FY89	FY90	FY91	FY92	FY93
Measurements	0.6M	0.5M	0.5M	0. 1M	
Information bases	1.0M	1.5M	1.0M	1.0M	1.0M
Modeling	2.3M	5.OM	5.OM	5.OM	3.1M
Scene generation	0.9M	1.5M	2.OM	2.OM	2.OM
Program management	0.2M	0.2M	0.2M	0.2M	0.2M
TOTAL	5.OM	8.7M	8.7M	8.3M	6.3M

11. Program Reviews

Reviews for the DoD Advisory Board formed to provide oversight and focus to the program are planned for the 2nd and 4th quarters of FY89. Project accomplishments will be presented to the BTI program office during the 4th Quarter. Products of the tasks identified will be reported on and provided to users in the DTE community as they become available. Progress of individual agency contributors will be monitored through quarterly meetings by the Program Manager, Integration Manager and the four Technical Area Managers.

12. Contracting Status

This program provides for the combined efforts of the DoD environmental sciences community to integrate and develop information bases, measurement tools, models and simulation technologies to predict the effects of the environment on the performance and effectiveness of smartweapon systems and autonomous target recognition (ATR) techniques. Performing agencies will determine the levels of in-house and contracted efforts required to provide the products for each task. Specific agency responsibilities and funding levels are being negotiated. The agencies have indicated that contractors will be involved in conduct of work under assigned tasks through existing task order contracts and new, competed contracts. Agencies have completed Broad Agency Announcements which include descriptions of efforts within this program which will serve to generate proposals of novel and innovative approaches for completion of tasks.

13. DoD Partners

Agencies participating in the program include:

Cold Regions Research and Engineering Laboratory
Atmospheric Sciences Laboratory
Engineer Topographic Laboratory
Waterways Experiment Station
CECOM Center for Night vision & Electro-Optics
Defense Advanced Research Projects Agency

Air Force Geophysics Laboratory
Air Force Armament Laboratory

Naval Ocean Research and Development Activity
Naval Environmental Prediction Research Facility Navy Pacific Missile Test Center
Naval Research Laboratory
Office of Naval Technology

14. Accomplishments

Demonstration of the cooperative process between Army, Navy and Air Force showing the integration of measurements to data bases to models to simulation to produce a credible 4-D set of environmental factors relevant to future smart munitions.

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13. ABSTRACT (*Maximum 200 words*)
The purpose of this effort is to provide the smart weapons and autonomous target recognition (ATR) communities with a validated capability to integrate: measurements, information bases, modeling and scene simulation; to effectively consider and exploit the complex environment of world wide battlefields. Information and analytical tools that comprehensively treat the environment in terms significantly relevant to weapon and sensor performance will be developed and demonstrated for two primary user communities: "designers/developers" and "testers/ evaluators."
The short term goals (91-92), long term goals (93-96), relationship to other programs, transition, program tasks and associated tasks are explained in this program implementation plan.

14. SUBJECT TERMS
autonomous target recognition; information bases; modeling/scene simulation; environment; measurement tools

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